# In Situ Bioremediation of Perchlorate in Groundwater

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DoD EPA DOE SERDP
Strategic Environmental Research and Development Program
Improving Mission Readiness Through Environmental Research

# SERDP/ESTCP

ESTCP
ENVIRONMENTAL SECURITY TECHNOLOGY CERTIFICATION PROGRAM

## SERDP

- **Research on In Situ Remediation (FY00-FY02)**
- **Ecotoxicity (FY99-FY01)**

## ESTCP

- **In Situ Remediation Demonstrations (FY02 New Starts)**

# SERDP Efforts - Remediation

**University of Southern Illinois (Dr John Coates)**

- Isolation and identification of $ClO_4$-degrading bacteria
- Development of rapid identification test kit for $ClO_4$-reducers

**Envirogen (Dr Paul Hatzinger) & USN - Indian Head (Carey Yates)**

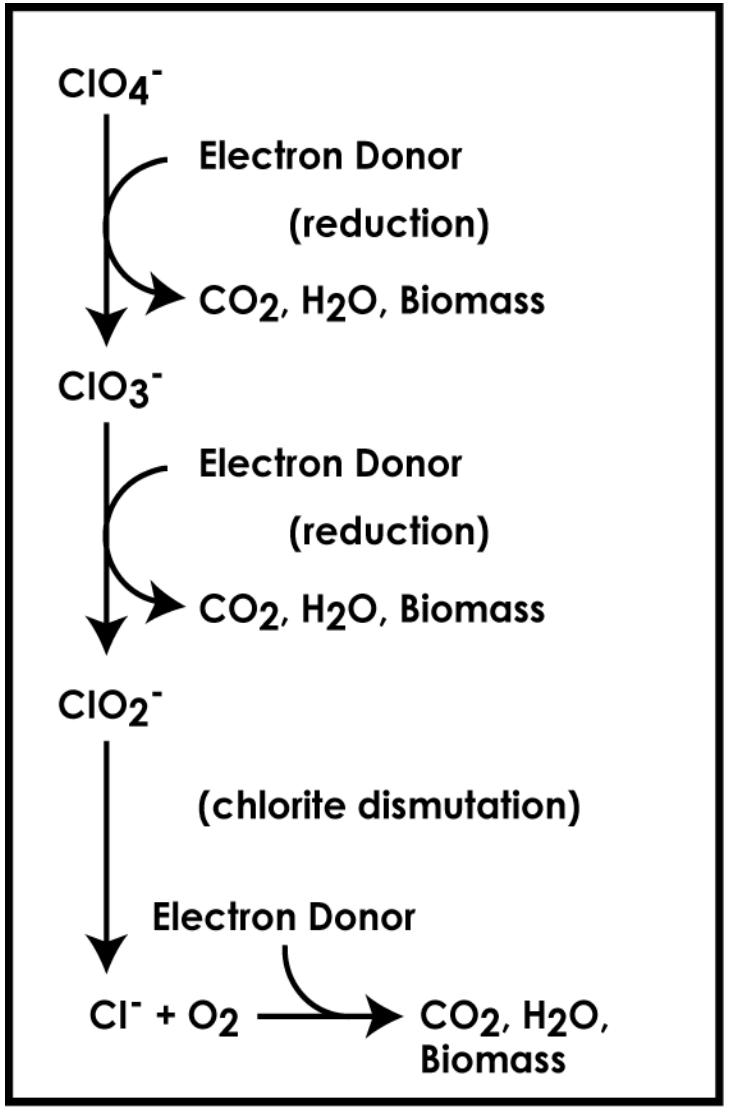
- Define key environmental factors affecting $ClO_4$ biodegradation
- Column studies to determine kinetic parameters for $ClO_4$ reduction
- Update current flow/reactive transport models to include $ClO_4$

**GeoSyntec (Evan Cox) & U. of Toronto (Dr Elizabeth Edwards)**

- Microcosm studies to assess ubiquity of $ClO_4$-reducers & assess joint biodegradation of $ClO_4$ & solvents
- Field demonstration of in situ bioremediation

**DoD Liaison - Bryan Harre (NFESC)**

# Accomplishments




- **Perchlorate-reducers appear to be ubiquitous in subsurface environments**
- **Use perchlorate as an electron acceptor**
- **A wide variety of carbon substrates can serve as electron donors**
- **Reaction occurs under anaerobic-reducing conditions**

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# Accomplishments

## Collected Aquifer Samples from Multiple Sites

**Envirogen**

**Jet Propulsion Lab, CA**

**Indian Head NSWC, MD *(2 Sites)***

**Rocky Mountain Commercial Site**

**Oyster Virginia (*Pristine Site*)**

**Longhorn AAP, TX *(3 Sites)***

**GeoSyntec**

**Aerojet Superfund Site ITRCS, CA**

**Edwards AFB, CA**

**U.S. Navy San Nicolas**

# Accomplishments

| Substrate | Jet Propulsion Lab | Rocky Mountain | Indian Head (Bldg 1170) | Indian Head (Hogout) |
|---|---|---|---|---|
| Hydrogen | | | | |
| Propane | | | NA | |
| Acetate | | | | |
| Lactate | | | NA | |
| Benzoate | | | NA | |
| Methanol | | | NA | |
| Ethanol | | | | |
| Molasses | | | | |
| YE/Ethanol | | | NA | |
| Sucrose | | | NA | |
| FBR2-Culture | | | | |

## *Preliminary Conclusions from Microcosm Studies*

- **Choice of Electron Donor Site Specific**
- **Low pH (< 5) Inhibitory to Perchlorate Degradation**
- **Oxygen Inhibitory to Perchlorate Degradation**
- **Nitrate and Nitrite Degraded before Pe**
- **J roblematic at**

**Rapid Biodegradation (≤ 14 Days**
**Slow Biodegradation (≥ 14 Days)**
**No Biodegradation**

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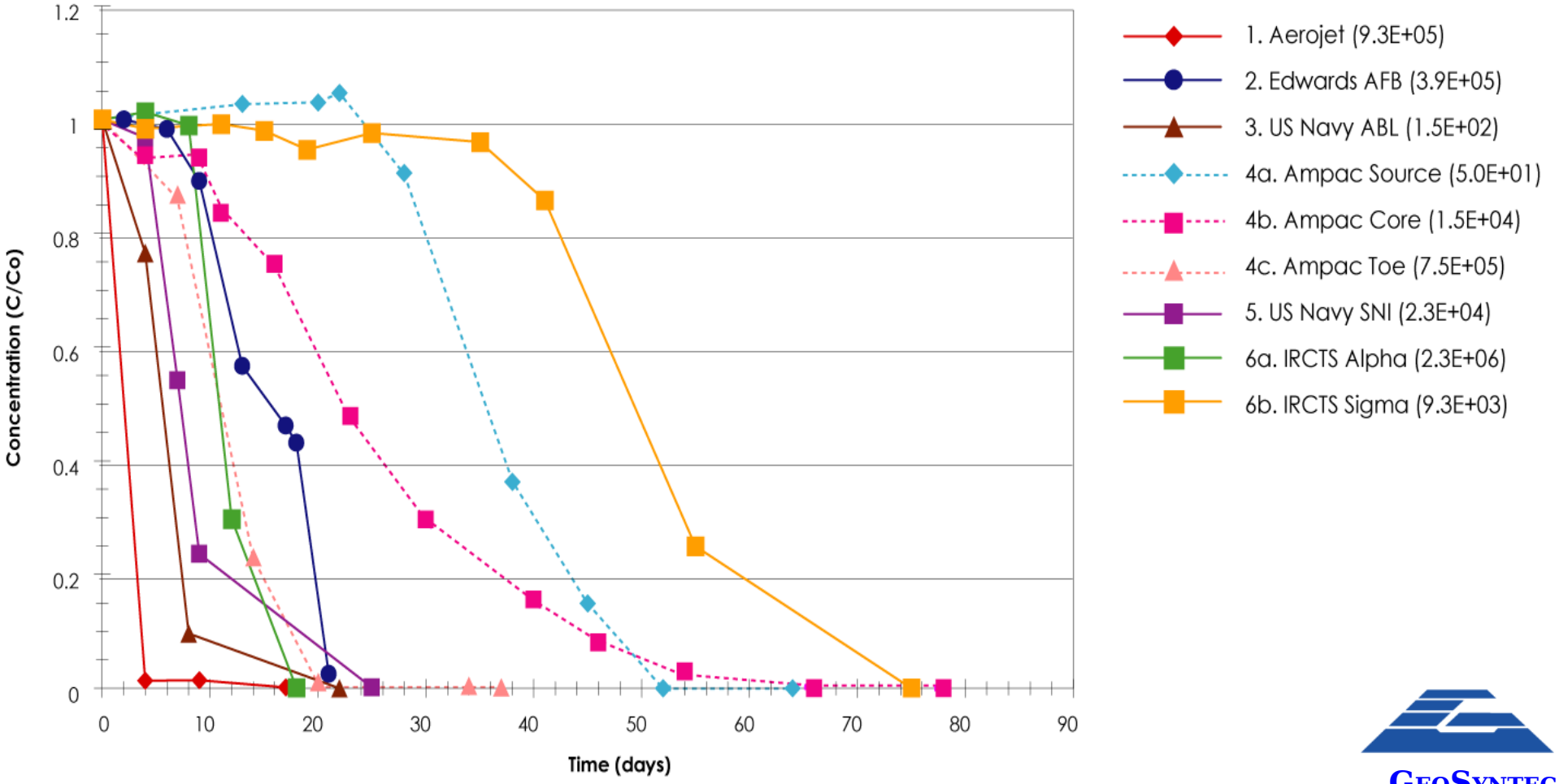
# Accomplishments

ESTCP

## $ClO_4$ Biodegradation in Acetate Treatments - All Sites
## MPNs for Perchlorate-Degraders (cells/mL) in Parentheses

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SERDP Strategic Environmental Research and Development Program
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# Accomplishments

ESTCP Environmental Security Technology Certification Program

## Summary of Electron Acceptor Use

| Site # | Site Name | Nitrate Concentration (mg/L) | Perchlorate Concentration (mg/L) | Sulfate Concentration (mg/L) | Order of Acceptor Utilization |
|---|---|---|---|---|---|
| 1 | Aerojet | 5.0 | 110 | 15 | **N = P > S** |
| 2 | Edwards AFB | <1.2 | 102 | 179 | **P > S** |
| 3 | US Navy - ABL | 3.8 | 9.8 | 54 | **N = P > S** |
| 4a | AMPAC Source | 7.6 | 92 | 1620 | **N > P > S** |
| 4b | AMPAC Core | 59 | 329 | 633 | **N = P > S** |
| 4c | AMPAC Toe | 30 | 666 | 473 | **N > P > S** |
| 5 | US Navy - SNI | 4.0 | 100 | 85 | **N > P = S** |
| 6a | IRCTS Alpha | 1.0 | 102 | 19 | **N > P = S** |
| 6b | IRCTS Sigma | 4.4 | 42 | 16 | **N > P < S** |

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# Planned Activities



- **Development of a molecular probe for rapid detection of perchlorate-reducers**
- **Field-scale experiment of in situ bioremediation starting Mar 01**
  - **Aerojet Superfund Site, California;**
- **Expected completion - December 2001**

# Conclusions Thus Far

- Perchlorate-degrading bacteria appear to be
- In situ bioremediation appears to be robust
  - Groundwater source or plume core destru
  - Migration control
- Key challenge will be electron donor deliver
- Acetate appears to be best substrate
- Potential for slow-release donors - edible oil
- Potential competitive effects due to nitrate

# SERDP Efforts - Ecotoxicology

## Texas Tech University (CU-1141 & CU 1223)

- Aquatic Toxicology - evaluate potential perchlorate-induced effects in amphibians and fish.
- Terrestrial Toxocology
  - Soil Ecotoxicology: Evaluate potential for perchlorate bioaccumulation in earthworms.
  - Rodents: Determine effects of perchlorate on thyroid hormone activity, development and reproduction in wild rodents.
  - Medium Sized Mammals: Determine effects of perchlorate on thyroid hormone activity in higher trophic level organisms associated with a terrestrial/aquatic interface.
- Molecular Toxicology: Identify/characterize molecular markers that are indicators of perchlorate exposure in amphibians, reptiles, and mammals.
- Environmental Modeling: Develop a terrestrial food chain and an aquatic food chain model for perchlorate.

## Southern Nevada Water Authority (CU 1222)

- Lab and field studies to determine the toxicological impact of ammonium perchlorate on fish.  Field studies to be done on carp in Lake Mead.

# SERDP Efforts - Ecotoxicology
# FY01 New Start Projects

## Texas Tech University (CU-1235)

- Avian Exposure Studies: Assess effects of perchlorate exposure to aquatic and terrestrial avian species. Assessments monitored via blood residues, thyroid hormone profiles, nesting success, survival, growth of fledglings, and residues in eggs.
- Food Item Transfer of Perchlorate into Rodents: Evaluate potential food web-related exposure pathways.
- Aquatic Toxicology:
  - Compare uptake of perchlorate in different fish species and different trophic levels
  - Examine perchlorate elimination rates in fish.
  - Using mosquitofish, examine effects of perchlorate exposure on gonadal histopathology, fecundity, egg volume and fry size, and fry growth in the laboratory.
  - Examine the effects perchlorate exposure to UV radiation sensitivity in frogs.
- Assess sensitivity of perchlorate toxicity to windows of development in amphibians and possible mitigating effects of naturally occurring iodine.
- Aquatic Plant Modeling: Adapt and integrate existing plant models into an aquatic food chain model and an avian PBPK model .

# SERDP Efforts - Ecotoxicology
# FY01 New Start Projects

## Oklahoma State University (CU-1236)

- Examine the Effects of Ammonium Perchlorate on Reproduction and Development
  of Amphibians:
  - Investigate effects of continuous long-term exposure.
  - Examine possible mitigating effects of naturally occurring iodine on perchlorate toxicity.
  - Determine the effect of perchlorate derived from food sources on amphibian development.
  - Investigate changes in pigmentation and sensitivity to UV radiation due to perchlorate exposure.
  - Observe the effects of perchlorate on reproductive capacity of female *Xenopus.*

# ESTCP FY02 Solicitation

"In Situ abiotic and biotic technologies are sought that specifically address that cleanup of groundwater contaminated with perchlorate. Technologies for the cost effective treatment of either aqueous phase plumes or the higher strength source zones are of interest."

- Anticipate selecting multiple technology demonstrations for funding.
- Contracts will be awarded March 02.
- Interested in conducting demos in partnership with